

# **Fuel Cell Demonstration Program – Central and Remote Sites 2002**

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## **ABSTRACT**

In an effort to promote clean energy projects and aid in the commercialization of new fuel cell technologies the Long Island Power Authority (LIPA) initiated a Fuel Cell Demonstration Program in 1999 with six month deployments of Proton Exchange Membrane (PEM) non-commercial Beta model systems at partnering sites throughout Long Island. These projects facilitated significant developments in the technology, providing operating experience that allowed the manufacturer to produce fuel cells that were half the size of the Beta units and suitable for outdoor installations.

In 2001, LIPA embarked on a large-scale effort to identify and develop measures that could improve the reliability and performance of future fuel cell technologies for electric utility applications and the concept to establish a fuel cell farm (Farm) of 75 units was developed. By the end of October of 2001, 75 Lorax 2.0 fuel cells had been installed at the West Babylon substation on Long Island, making it the first fuel cell demonstration of its kind and size anywhere in the world at the time.

Designed to help LIPA study the feasibility of using fuel cells to operate in parallel with LIPA's electric grid system, the Farm operated 120 fuel cells over its lifetime of over 3 years including 3 generations of Plug Power fuel cells (Lorax 2.0, Lorax 3.0, Lorax 4.5). Of these 120 fuel cells, 20 Lorax 3.0 units operated under this Award from June 2002 to September 2004.

In parallel with the operation of the Farm, LIPA recruited government and commercial/industrial customers to demonstrate fuel cells as on-site distributed generation. From December 2002 to February 2005, 17 fuel cells were tested and monitored at various customer sites throughout Long Island.

The 37 fuel cells operated under this Award produced a total of 712,635 kWh. As fuel cell technology became more mature, performance improvements included a 1% increase in system efficiency. Including equipment, design, fuel, maintenance, installation, and decommissioning the total project budget was approximately \$3.7 million.

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## INTRODUCTION

Long Island Power Authority (LIPA) realizes the importance of looking towards the future. LIPA provides electricity to 1.1 million customers on Long Island, including Nassau, Suffolk, and the Rockaway Peninsula in Queens. As a result of this responsibility, LIPA is faced with continually increasing energy needs. While striving to provide reliable, cost-effective service to customers throughout its territory, LIPA has made environmental concerns one of its top priorities.

The Long Island Power Authority's comprehensive program, the Clean Energy Initiative (CEI), is one of the most ambitious programs of its kind. The CEI encompasses nearly a dozen energy conservation programs and cutting-edge research, development and demonstration (RD&D) efforts. The Clean Energy Initiative is a ten year, \$355 million program, proposed by New York State Governor George Pataki, to foster the development and application of clean energy technologies, including fuel cells in LIPA territories.

LIPA's Fuel Cell Program (Program) began in 1999 as part of the CEI. The Program shares its objective of furthering commercialization of fuel cell power generators to reduce greenhouse gas emissions with the "2003 Climate Change Fuel Cell Program" of the Department of Defense. This commonality has enabled LIPA to receive financial support to supplement its Program through two awards funded through the Department of Energy's National Energy Technology Laboratory (NETL).

At the beginning of its Program LIPA partnered with Plug Power to demonstrate fuel cell systems' operational characteristics. The partnership emphasized learning and increased benefit to LIPA, its customers, and the evolving technology. Plug Power fuel cells were sold to LIPA under an agreement that included training, monitoring, engineering services, and technical support to operate and maintain the units. The fuel cell systems (FCS) were fully integrated to include a fuel processor, a fuel cell stack, and an inverter. The FCS's were designed to generate up to 5kW with a nominal voltage of 240V at 60Hz. Fueled by natural gas, the FCS produced very low emissions and low noise. While their operating temperature ranged from 255°K to 313°K, the FCS's were not designed for waste heat utilization.

In 2000, planning started for the construction of the Long Island Fuel Cell Farm. In 2001, LIPA constructed a 3-acre fuel cell site adjacent to the West Babylon substation. The operation and support of the fuel cell farm required the training of a local service provider. Through competitive bidding, Elemco of Bohemia, NY was selected. Elemco has since then become a valuable partner in the deployment of fuel cell technology throughout Long Island. Elemco's technicians were trained by Plug Power for the operation and maintenance of the fuel cells.

The West Babylon Farm site provided the initial platform for LIPA's Fuel Cell Demonstration program. The site was built to support the operation of ninety 5kW

fuel cells. In addition, this operation would determine grid impacts of large concentrations of fuel cells on the distribution grid.

The initial phase of fuel cell deployments for distributed generation at remote sites started in parallel with the Farm project. This phase began with an installation in July 2002 and ended in February 2005. Nine selected sites included government and commercial/industrial customers on Long Island: Nassau Community College, Hofstra University, Suffolk County Legislature, Hempstead Animal Shelter, East Hampton Town Hall, McDonald's in Deer Park, Babylon Town Hall, Southampton College, and SUNY Farmingdale. Per the site agreements with these customers, any cost of natural gas consumed by the fuel cells in excess of the electric output value of these fuel cells based on LIPA's electric rate was reimbursed by LIPA. This cost is referred to as the True-Up cost.

A list of the 37 Lorax 3.0 FCS and their locations is listed in Table 2.



## EXECUTIVE SUMMARY

In 1999 LIPA began its Fuel Cell Program as part of its Clean Energy Initiative Program which works with customers, equipment manufacturers, and the energy marketplace to promote energy conservation and clean energy technologies to reduce greenhouse gas emissions. By partnering with Plug Power in 1999 to begin testing and demonstrating fuel cell power plants, LIPA began its effort to support the commercialization of the technology. Originally, 6 Beta model systems were installed at 4 laboratories of partnering sites including Brookhaven National Laboratories, Hofstra University, US Merchant Marine Academy, and State University of NY at Stony Brook. This initiative facilitated several technology advances such as significant reductions in equipment size and costs.

With the lessons learned and developments of the units from Plug Power, LIPA embarked on a multi-million dollar fuel cell demonstration Fuel Cell Farm project focusing on increasing its energy supply to meet the growing energy demands on Long Island without noticeably increasing its greenhouse gas emissions.

From 2001 to 2004, LIPA installed and demonstrated 120 fuel cell systems (FCS) at the Farm in West Babylon, NY. The first phase of the Farm consisted of testing 75 Lorax 2.0 fuel cell systems (FCS) simultaneously while occupying the maximum capacity of the Farm. To support further design improvements, 20 FCS of the following generation, Lorax 3.0, were tested as part of the second phase from June 2002 to September 2004.

In parallel to the Farm project, LIPA began the remote deployment of 17 additional Lorax 3.0 FCS. From August 2002 to February 2005, these 17 FCS were sited for distributed generation applications at commercial and government facilities as part of the Remote Sites Demonstration project. Each unit operated in parallel to the grid for a minimum period of 12 months supplying power to the facilities and reducing their dependencies on the utility grid.

Systems developed by the FCS manufacturer and a third-party consultant enabled near real-time monitoring of all FCS. These systems monitored key performance parameters while providing alarm notifications when units shut down.

The 37 Lorax 3.0 FCS operated under this Award produced a total of 712,635 kWh. The mean time between failures for these FCS was 2,404 hours (100 days). These units were available and generating 65% of their operational terms with an electrical efficiency of 23.4%. These units were not designed to allow the recovery of the waste heat or thermal output. From generation to generation, improvements included increases in availability and system efficiency. Including equipment, design, fuel, and maintenance, the total project budget was approximately \$3.7 million. The resulting cost of the project is \$4.95 per kWh.

## EXPERIMENTAL

In order to capture performance data, two monitoring systems were used for all fuel cells: Plug Power Quality Tracking Management System (QTMS), and Connected Energy Corporation Central Operation Management System (COMSYS). The COMSYS interface was web-based – sample information is provided in Figure 1. Key parameters captured from either/or both monitoring systems included:

- Average Electric Output
- kWh Energy Output
- Electrical Efficiency
- Site Availability
- Fuel Usage
- Capacity Factor
- Availability

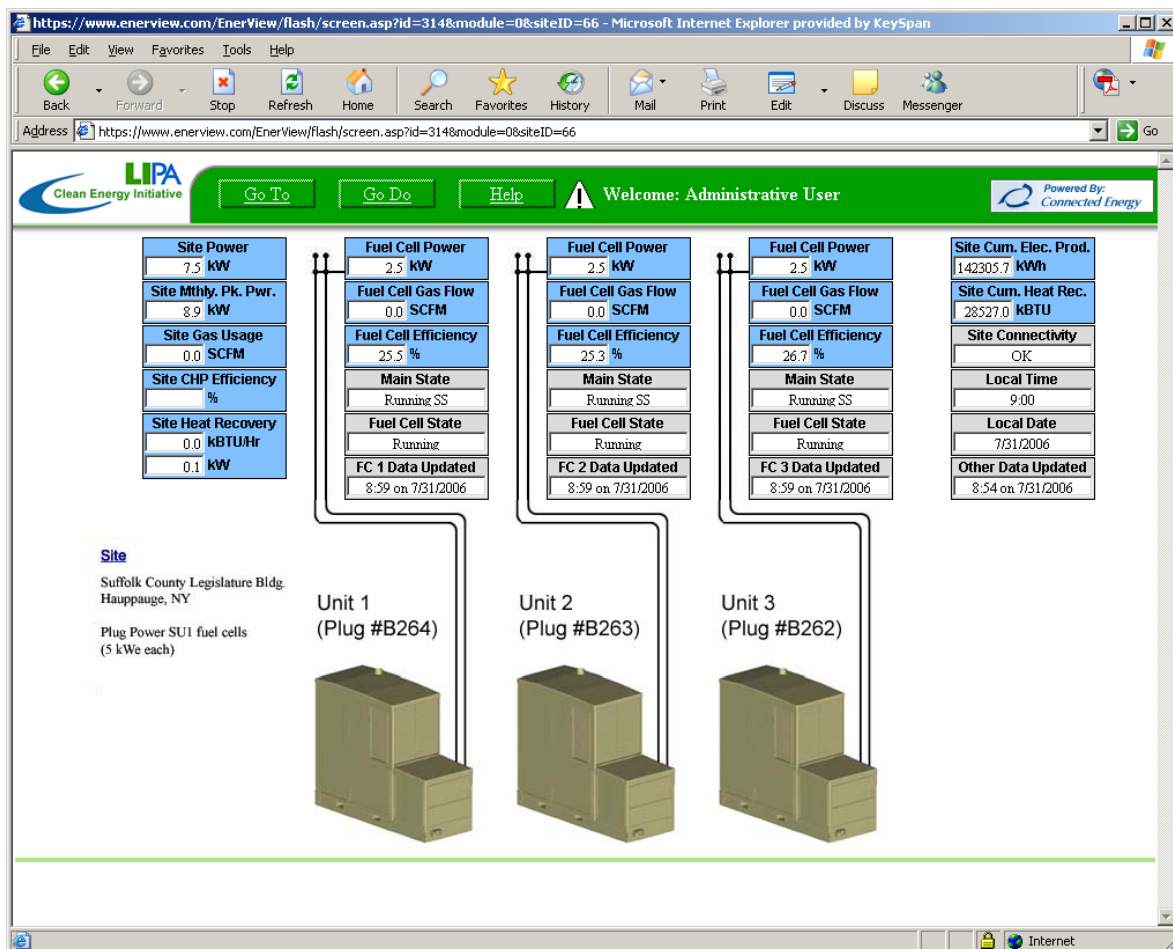


Figure 1: COMSYS Website

The Lorax 3.0 SU1 is designed to automatically send operational data (sampled every 10 minutes) once per day, via modem/dial-up connection, to Plug Power. Once at Plug Power, the data is entered into the fleet QTMS database.

Furthermore, during every system shutdown, the unit automatically reports to Plug Power its status, error logs and high-speed data. The high-speed data is a packet of data-points taken at a much higher resolution (every second for the last 10 minutes). This information is used to track preventative maintenance items, troubleshoot failures, and dispatch field service technicians. Complete system operational data can also be downloaded directly from the machine by a trained service technician with a laptop and RS232 connection cable.

Additionally, through the Connected Energy's COMSYS, data points were collected via a remote monitoring cabinet using Modbus protocol for communication with the fuel cells. Data was transmitted back to Connected Energy via a phone line with DSL service. A secured website was developed by Connected Energy to report near real-time (5-15 seconds) parameters and alarms near real-time (Figure 1). This information was also used for maintenance purposes and to dispatch service technicians in the case of a communication failure with the fuel cell integrated monitoring system.

## RESULTS AND DISCUSSION

The 37 FCS listed in Table 2 were fueled by natural gas. Though they were designed to supply up to 5kW of power, their output were set at 2.5kW during normal operation. At the Farm, the FCS were connected to the utility grid, and at the Remote Sites they operated in parallel to the grid supplying power to the facilities. Table 1 lists the Lorax 3.0 target specifications.

**Table 1: Lorax 3.0 Fuel Cell Specifications**

SU1 Lorax 3.0 Target Specifications	
<ul style="list-style-type: none"><li>• Size: 2.13m L x 0.81m W x 1.73m H (84"L x 32"W x 68 1/4"H); exhaust height – 0.56m (22")</li><li>• Grid parallel operation only</li><li>• Natural gas fueled</li><li>• Power Output / Setpoints: 2.5 kW, 4 kW, 5 kW</li><li>• Voltage: 240 VAC @ 60 Hz.</li><li>• Performance (simple cycle efficiency at beginning of life, 298°K (77°F), 500 ft.)</li><li>• 26% @ 2.5 kW</li><li>• 25% @ 4.0 kW</li><li>• 21% @ 5.0 kW</li></ul>	
<hr/>	
<ul style="list-style-type: none"><li>• Waste Heat Utilization: None</li></ul>	
<ul style="list-style-type: none"><li>• CSA Certified; Power Conditioning Module, including the Inverter UL Certified</li><li>• Power Quality: IEEE 519</li><li>• Emissions (steady-state @ 2.5 kWe)</li><li>• NOx &lt; 5 ppm</li><li>• SOx &lt; 1 ppm</li><li>• CO &lt; 50 ppm</li></ul>	
<ul style="list-style-type: none"><li>• Standard operating conditions</li></ul>	
<ul style="list-style-type: none"><li>• CSA Certified for outdoor operation only</li><li>• Elevation: 0 to 228.6m (750 ft)</li><li>• Noise: &lt; 70 dBa @ 1 meter</li><li>• Operating Temperature: 255°K to 313°K (0 °F to 104 °F)</li></ul>	

**Table 2: List of Lorax 3.0 SU1 Fuel Cells - Award No. DE-FG26-03NT42021**

Serial #	Date of Purchase	Commission Date	12-month Completion Date	Location
SU1000000099	2/21/2002	12/6/2002	12/6/2003	McDonalds
SU1000000110	2/21/2002	7/31/2003	7/31/2004	Suffolk County
SU1000000124	2/21/2002	11/6/2002	11/6/2003	East Hampton
SU1000000140	2/21/2002	7/18/2002	7/18/2003	W Babylon Town Hall
SU1000000143	2/21/2002	8/20/2002	8/20/2003	Hofstra University
SU1000000145	2/21/2002	8/20/2002	8/20/2003	Hofstra University
SU1000000146	2/21/2002	7/31/2003	7/31/2004	Suffolk County
SU1000000147	2/21/2002	8/20/2002	8/20/2003	Hofstra University
SU1000000151	2/21/2002	10/24/2003	10/24/2004	Hempstead Animal Shelter
SU1000000153	2/21/2002	7/31/2003	7/31/2004	Suffolk County
SU1000000154	2/21/2002	5/7/2003	5/7/2004	SUNY Farmingdale
SU1000000155	2/21/2002	9/24/2003	9/24/2004	Nassau Community College
SU1000000156	2/21/2002	5/7/2003	5/7/2004	SUNY Farmingdale
SU1000000157	2/21/2002	9/24/2003	9/24/2004	Nassau Community College
SU1000000160	2/21/2002	5/6/2003	5/6/2004	SUNY Farmingdale
SU1000000184	2/21/2002	10/15/2003	10/15/2004	South Hampton
SU1000000205	2/21/2002	10/15/2003	10/15/2004	South Hampton
SU1000000109	2/21/2002	6/28/2002	6/28/2003	West Babylon Substation (Farm)
SU1000000111	2/21/2002	7/1/2002	7/1/2003	West Babylon Substation (Farm)
SU1000000112	2/21/2002	7/1/2002	7/1/2003	West Babylon Substation (Farm)
SU1000000113	2/21/2002	6/28/2002	6/28/2003	West Babylon Substation (Farm)
SU1000000114	2/21/2002	6/28/2002	6/28/2003	West Babylon Substation (Farm)
SU1000000115	2/21/2002	7/10/2002	7/10/2003	West Babylon Substation (Farm)
SU1000000116	2/21/2002	6/28/2002	6/28/2003	West Babylon Substation (Farm)
SU1000000117	2/21/2002	6/28/2002	6/28/2003	West Babylon Substation (Farm)
SU1000000118	2/21/2002	6/28/2002	6/28/2003	West Babylon Substation (Farm)
SU1000000119	2/21/2002	1/15/2003	1/15/2005	West Babylon Substation (Farm)
SU1000000120	2/21/2002	7/5/2002	7/5/2003	West Babylon Substation (Farm)
SU1000000127	2/21/2002	7/5/2002	7/5/2003	West Babylon Substation (Farm)
SU1000000128	2/21/2002	6/28/2002	6/28/2003	West Babylon Substation (Farm)
SU1000000130	2/21/2002	7/2/2002	7/2/2003	West Babylon Substation (Farm)
SU1000000131	2/21/2002	6/28/2002	6/28/2003	West Babylon Substation (Farm)
SU1000000134	2/21/2002	8/8/2002	8/8/2003	West Babylon Substation (Farm)
SU1000000137	2/21/2002	8/7/2002	8/7/2003	West Babylon Substation (Farm)
SU1000000149	2/21/2002	6/28/2002	6/28/2003	West Babylon Substation (Farm)
SU1000000150	2/21/2002	6/28/2002	6/28/2003	West Babylon Substation (Farm)
SU1000000152	2/21/2002	6/24/2002	6/24/2003	West Babylon Substation (Farm)

## Fuel Cell Farm

The initial deployment in October 2001 of 75 units represented a micro-grid of 75 homes connected to A, B, and C phases of the distribution grid. While each FCS is designed to supply 240V at 60Hz, the Farm layout and electrical work was designed to supply power to the grid on all 3 phases. At that time, this project represented the largest deployment of fuel cells in the world. Through the course of the project, the Farm was repopulated several times with newer generations of fuel cell technology including the 20 units identified under this Award. Figure 2 and Figure 3 show how the fuel cells were physically setup at the Farm.

These 20 Lorax 3.0 systems were installed in 2002 and operated until the first quarter of 2004.



**Figure 2: Farm Fuel Cell Layout**



**Figure 3: Fuel Cell Farm**

The table below summarizes the combined Lorax 3.0 Farm fuel cells' performance over their operational life.

**Table 3: Farm output for 20 Lorax 3.0 SU1 fuel cells**

Site	Serial #	Run Hours	Average Elec. Output	Electrical Efficiency	Availability	Energy Output
Farm - Lorax 3	(refer to Table 2)	163,487	2.51 kW	24.12%	65.25%	410,106 kWh

The Lorax 3.0 generations of fuel cells at the Farm were operational 65.25% of the time for a total of about 163,487 hours. The average electrical efficiency was 24.12%, an increase of approximately 1% over the average of the 75 Lorax 2.0 initially installed at the Farm. Each Lorax 3.0 unit produced on average 20.5 MWhrs of energy and the average output was 2.51 kW.

In general, the Lorax 2.0 and 3.0 units were similar in their performance. Even though the latter was more efficient over its lifetime, the Lorax 2.0 systems had higher average availability.

The Lorax 3.0 Farm project produced 410,106 kWh and cost a total of \$2,053,842 (Table 4); resulting in an overall project cost of \$5.01 per kWh. The combined energy output of the units at the Farm accounted for an emission savings of 902 kg (1,988 lbs) of SO<sub>2</sub>, 283 kg (625 lbs) of NO<sub>x</sub>, and 48,488 kg (106,897 lbs) of CO<sub>2</sub>.

Site	Equipment/ Installation	Maintenance/ Service	Fuel	Decommissioning	Total
Farm (20 units)	\$1,540,000	\$380,840	\$103,002	\$30,000	\$2,053,842

**Table 4: Farm Costs**

The construction and maintenance of the Farm has provided unique opportunities for working in partnership with local governments, equipment suppliers, manufacturers, the U.S. Department of Energy, and foreign entities. The Farm site provided a test bed for LIPA and the utility industry to investigate the critical issues related to distributed generation devices.

### Remote Sites

The remote sites deployment of fuel cells began in July 2002 with the first installation of a Lorax 3.0 system at the Babylon Town Hall (government customer). This installation was followed by 16 others at various commercial and other government customers on Long Island including 3 at the offices of Suffolk County Legislature in Hauppauge, NY (Figure 4) – a complete list of sites is included in Table 2. All systems operated for a period of 12 to 18 months.



**Figure 4: Fuel Cells at Suffolk County Legislature**

Sixteen of the remote site fuel cells were Lorax 3.0 systems. The fuel cell installed at a McDonald's restaurant in Deer Park (Figure 5) consisted of a Lorax 2.0 system similar to the initial 75 units deployed at the Farm in 2001. Significant improvements in Lorax 3.0 technology include electrical efficiency with an average increase of nearly 7% over the Lorax 2.0. In general, the unit tested at McDonald's did not perform as well as the Lorax 3.0.



**Figure 5: Fuel Cell at McDonald's in Deer Park**



**Table 5: Remote Sites Output for 17 Lorax 3.0 SU1 Fuel Cells**

Site	Serial #	Total Hours in Period	Run Hours	Average Elec. Output (kW)	Electrical Efficiency	Availability	Capacity Factor	Energy Output (kWh)	Fuel Usage (BTU)
Nassau Community College	SU1000000155	8,760	6,556	2.41	24.87%	74.84%	36.01%	15,771	216,327,590
	SU1000000157	9,703	7,980	2.49	23.36%	82.25%	41.01%	19,897	290,650,811
<b>TOTAL</b>		<b>18,463</b>	<b>14,537</b>	<b>2.45</b>	<b>24.12%</b>	<b>78.54%</b>	<b>38.51%</b>	<b>35,668</b>	<b>506,978,400</b>
Hofstra University	SU1000000143	9,480	6,608	2.48	24.49%	69.70%	34.54%	16,370	228,100,389
	SU1000000145	8,616	5,701	2.47	20.93%	66.17%	32.66%	14,071	229,378,353
	SU1000000147	8,760	3,847	2.29	20.73%	43.91%	20.15%	8,824	145,204,211
<b>TOTAL</b>		<b>26,856</b>	<b>16,155</b>	<b>2.41</b>	<b>22.05%</b>	<b>59.93%</b>	<b>29.11%</b>	<b>39,265</b>	<b>602,682,953</b>
Suffolk County Legislature	SU1000000110	8,760	6,955	3.03	21.95%	79.39%	48.13%	21,079	327,650,948
	SU1000000146	9,480	5,308	2.44	23.19%	56.00%	27.31%	12,944	190,455,861
	SU1000000153	12,312	9,788	2.50	25.65%	79.50%	39.73%	24,460	325,400,563
<b>TOTAL</b>		<b>30,552</b>	<b>22,051</b>	<b>2.66</b>	<b>23.60%</b>	<b>71.63%</b>	<b>38.39%</b>	<b>58,483</b>	<b>843,507,372</b>
Hempstead Animal Shelter	SU1000000151	8,904	6,077	2.67	24.66%	68.25%	36.39%	16,199	224,150,555
East Hampton Town Hall	SU1000000124	18,024	11,807	2.27	21.09%	65.51%	29.77%	26,829	434,020,901
Mc Donald's in Deer Park	SU1000000099	11,292	7,558	1.46	15.95%	66.93%	19.52%	11,022	235,839,828
Babylon Town Hall	SU1000000140	19,071	17,222	2.32	21.39%	90.30%	41.91%	39,962	637,301,481
Southampton College	SU1000000184	8,952	6,355	2.48	26.03%	70.99%	35.17%	15,743	206,367,928
	SU1000000205	8,952	4,756	2.43	20.75%	53.12%	25.82%	11,555	189,988,008
<b>TOTAL</b>		<b>17,904</b>	<b>11,111</b>	<b>2.45</b>	<b>23.39%</b>	<b>62.06%</b>	<b>30.49%</b>	<b>27,298</b>	<b>396,355,935</b>
SUNY Farmingdale	SU1000000154	14,412	7,242	2.51	25.46%	50.25%	25.23%	18,180	243,651,637
	SU1000000156	13,572	7,052	2.48	23.31%	51.96%	25.73%	17,457	255,511,680
	SU1000000160	12,264	5,025	2.42	21.42%	40.97%	19.84%	12,164	193,772,632
<b>TOTAL</b>		<b>40,248</b>	<b>19,319</b>	<b>2.47</b>	<b>23.40%</b>	<b>47.73%</b>	<b>23.60%</b>	<b>47,801</b>	<b>692,935,949</b>
<b>TOTAL</b>	<b>17 units</b>	<b>191,314</b>	<b>125,836</b>	<b>2.42</b>	<b>22.66%</b>	<b>65.30%</b>	<b>31.70%</b>	<b>302,528</b>	<b>4,573,773,376</b>

Maintenance service calls for the fuel cell systems occurred in general every 3 to 4 months due to a shutdown. Services were considered to be scheduled outages in any one or combination of the following scenarios:

- 12,000 kWh of output service
- Telecommunication related service that did not relate to the electrical performance of the fuel cell system
- Follow-up to a previous service for an unplanned outage.

Table 6 summarizes the average maintenance requirements for all Lorax 3.0 fuel cells tested under this Award. The figures included in that table can also be applied to the 20 Farm fuel cell systems. Note that the numbers represent the average per unit per term of operation (12 to 18 months).

	Average Number of Scheduled Outages	Average Number of Unplanned Outages	Average Length of Service Calls (hours)	Mean Time Between Failure (MTBF) (hours)
Remote Sites (17 units)	1.08	4.31	5.39	2,404 (~ 100 days)

**Table 6: Average Maintenance Requirements**

Overall, the 17 fuel cell systems tested at remote sites produced a total of 302,528 kWh and cost a total of \$1,659,134 (Table 7); resulting in an overall project cost of \$5.48 per kWh. The combined energy output of the units at the Remote Sites accounted for an emission savings of 665 kg (1,466 lbs) of SO<sub>2</sub>, 209 kg (461 lbs) of NO<sub>x</sub>, and 35,768 kg (78,855 lbs) of CO<sub>2</sub>.

Site	Equipment/ Installation	Maintenance/ Service	True Up	Decommissioning	Total
Remote Sites (17 units)	\$1,552,000	\$27,186.30	\$29,760.43	\$50,186.99	\$1,659,134

**Table 7: Remote Sites Costs**

The installation, maintenance, and operation knowledge gained from this project became greatly beneficial to the deployment phases that followed in 2004 with the demonstration of 20 Lorax 4.5 fuel cell systems for commercial and residential applications.

## CONCLUSION

Since the inception of the Fuel Cell Program in 1999, one of LIPA's goals was to advance fuel cell technology as a clean, zero emission energy source that could reduce the current electric load on the transmission and distribution system. Indeed, LIPA's various demonstrations and testing of the Lorax 3.0 fuel cells led to significant technology advances resulting in increased efficiency and availability, decreased equipment size and costs. This project also resulted in great operational experience for LIPA, Plug Power, and the service contractor. Experience and lessons learned led to quicker response time and repair time for the service contractor. As the knowledge base grew installation and maintenance costs decreased.

The 20 Lorax 3.0 fuel cells from the Farm and the 17 similar systems tested at remote sites produced a total of 712,635 kWh. This clean energy production accounted for an emission savings of 1,567 kg (3,454 lbs) of SO<sub>2</sub>, 493 kg (1,086 lbs) of NO<sub>x</sub> and 84,256 kg (185,752 lbs) of CO<sub>2</sub>.

The project cost a total of approximately \$3.7 M, with 88% of that cost emanating from equipment and installation costs. Maintenance outlays accounted for 11% of the total cost; and Fuel, True Up, and Decommissioning costs accounted for the remaining 1%. The overall resulting project rate was \$5.21/kWh.

These early phases of the Farm and Remote Sites deployment led to a later phase that would deploy 45 fuel cells of the later generation, 25 at the Farm, and 20 at remote sites. This new generation of fuel cells would include improvements such as reduction in unit dimension, reduction in equipment cost, and added ability to recover waste heat, therefore increasing overall system efficiency.



"Fuel cells hold great promise, as an environmentally friendly electric generating technology. We need to develop an understanding of how fuel cells can be integrated with our electric grid, and that's what this project will help identify."

- Richard Kessel, LIPA Chairman

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